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[0005]

Means for Solving the Problem, and Its Operation and Effects

In order to solve the problems described above, a joining bump-mounted circuit board according to Claim 1 of the present invention includes a substrate and a plurality of joining bumps disposed on a joining surface thereof, and is characterized as follows. The substrate is designed so as to be superposed with a joined object, such as another substrate or an integrated circuit chip, facing the joining surface, and heated to a predetermined joining temperature, so that the joined object is joined via the joining bumps. These joining bumps are partially melted at the joining temperature to produce a liquid phase, and a state is formed where the generated liquid-phase part and the remaining solid phase part are mixed with one another.

[0006] It should be noted that the "circuit board" referred to here is not just a substrate on which an integrated circuit chip is mounted, but also means a substrate joined to a printed circuit board and an integrated circuit chip itself (that is, a flip chip). More specifically, this refers to a substrate that has a plurality of solder bumps provided on one surface for joining to an integrated circuit chip (flip-chip joining), a substrate that has a plurality of solder bumps (in this case, a standard ball grid array) provided on one surface to join to a printed circuit board, or an integrated circuit chip having a plurality of solder bumps. This plurality of bumps can be arranged on a line or on a plane. One example of a linear arrangement pattern is an arrangement in a rectangular frame. One example of a planar arrangement pattern is an arrangement in a lattice or a staggered pattern.

[0007] For a circuit board of the above construction, at the joining temperature, the joining bumps partially melt, producing a liquid phase, and this liquid phase is supplied to the joins between the joined object and the joining bumps, and after this the liquid phase cools and solidifies, thereby joining the substrate and the joined substrate via the joining bumps. Here, the joining bumps are formed in a state where the liquid phase and the solid phase become mixed together at the joining temperature, so that there is no risk of problems such as the bumps completely melting and collapsing as occurs with bumps made using eutectic solder.

[0008] These joining bumps are formed in a state where both solid phase and liquid phase exist at the joining temperature (hereinafter also referred to as the "solid-liquid coexistent state"), and can be made of an alloy that at the joining temperature is composed of 20 to 95% by weight of the solid phase (Claim 2). That is, according to this construction, it is easy to manufacture joining bumps, which at the joining temperature reach a state where the solid phase part and the liquid phase part are mixed, from alloy, so that it is not necessary to use a step or equipment for mounting balls, such as with conventional bumps that enclose balls. This means that the manufacturing cost can be reduced and small bumps can be manufactured easily.

[0009] It is believed that the bumps described above do not readily collapse during joining due to the reasons given below. For example, in the case where the entire bumps are converted to the liquid phase during joining, the force required to maintain the bump shape is almost exclusively provided by surface tension, so that the bumps will collapse when subjected to even a small external force. However, in the case

where there is the solid-liquid coexistent state (that is, a semi-molten state) as with the bumps of the above construction, if the bumps attempt to flow and change shape, there is an increase in what looks like viscosity due to friction at the interfaces between the solid state parts and the liquid phase parts, so that during joining the retentivity of the form of the bumps is increased. Also, it is possible to use a skeletal construction, such as a three-dimensional mesh, in which the solid phase parts are joined together, and in this case, since it becomes necessary to deform the skeletal structure to deform the bumps, the retentivity of the form of the bumps is further improved.

[0010] It should be noted that if an alloy where the proportion of the solid state part is less than 20% by weight at the joining temperature is used to compose the joining bumps, there will be an increase in the fluidity of the bumps and there are cases where a sufficient effect for preventing collapse of the bumps cannot be achieved. On the other hand, if an alloy where the proportion of the solid state exceeds 95% by weight is used, insufficient liquid phase will be produced, so that there are cases where a sufficient join cannot be formed between the joined object and the bumps. This means that an alloy with a proportion of solid phase of 20 to 95% by weight should preferably be used, with it being even more preferable to use an alloy with a proportion of solid phase of 40 to 70% by weight.

[0011] Bumps produced using the kind of alloy described above can be formed by a so-called "solder pasting" method where a predetermined bump pattern is formed on the substrate using a paste of alloy powder, for example, and this is then heated to a melting start temperature of the alloy or above so that at least some of the alloy powder particles

included in the paste melt and are integrated. On the other hand, it is also possible to use a performing method that manufactures an alloy by combining and intermixing raw materials in a predetermined composition, that produces "performs" by molding the alloy into a predetermined form by casting and machining processes, mounts these performs on a substrate and then heats them to the melting point of the alloy or above to integrate the performs with the substrate, thereby forming the bumps. It should be noted that in this specification, the expression "melting start temperature" encompasses a melting point, a solidus temperature, a eutectic temperature, a peritectic temperature, and the like, and so is a general name for a temperature at which a metal or alloy starts to melt during a rise in temperature.

[0012] The joining bump-mounted circuit board according to Claim 3 has a substrate and a plurality of joining bumps, the joining bumps being composed of an alloy that reaches a state where solid phase and liquid phase are coexistent at least in a temperature range of 200 to 220°C and where a proportion of solid phase is 20 to 95% by weight in the stated temperature range. That is, the joining bumps of this circuit board are formed from an alloy in which the solid-liquid coexistent state is formed with the proportion of solid phase being 20 to 95% by weight in at least a temperature range of 200 to 220°C that is widely used during a joining process for conventional circuit boards having bumps made of eutectic solder, so that when the joining process is carried out in the stated temperature range, in the same way as the circuit board of Claim 2 described above, problems such as the bumps collapsing do not occur and favorable joins with the joined object can be formed. Putting this another way, it is possible to carry out the joining process with the same joining temperature conditions as a substrate

including eutectic solder bumps.

[0013] The joining bumps in the construction described above can be composed of an alloy that has one or two or more elements selected from Pb, Sn, and Au as its principal components (Claim 4). For example, an alloy including a total of at least 80% by weight of at least one of Pb and Sn (for example, a Pb-Sn solder alloy or an Sn-Pb solder alloy) is a general-purpose material that is inexpensive and has superior brazing characteristics, and can be favorably used for the joining bumps of the circuit board according to the present invention (Claim 5). It should be noted that if the alloy forms a solid-liquid coexistent state with the proportion of the solid phase at 20 to 90% by weight or preferably 20 to 90% by weight at least within the temperature range of 200 to 220°C, an alloy with a total of less than 80% of Pb and/or Sn can still be favorably used as the material for the joining bumps according to the present invention. Aside from a Pb-Sn alloy, an Au-Tl alloy or the like may be used.

[0014] When the joining bumps are formed of an alloy where the total amount of included Pb and Sn is at least 80% by weight, for example, by setting the proportion of the Sn in a range of 20 to 40% by weight relative to the total weight of the Pb and the Sn, the proportion of the solid phase in a temperature range of 200 to 220°C can be adjusted to a range of 20 to 95% by weight, so that as described above, the collapsing of the bumps can be prevented and favorable joins can be formed (Claim 6). When the included proportion of Sn is less than 20% by weight, the proportion of the solid phase in the stated temperature range can exceed 95% by weight, while when the included proportion of Sn exceeds 40% by weight, the proportion of the solid phase in the stated

temperature range can fall below 20% by weight. It should be noted that to adjust the proportion of solid phase to a more preferable range of 40 to 70% by weight, the included proportion of Sn should be adjusted to a range of 28 to 33% by weight. It should be noted that as a more preferable alloy composition, it is possible to use a Pb-Sn binary alloy where the included proportion of Sn is 20 to 40% by weight.

[0015] The joining bumps may be composed of a mixture of a solid phase forming metal part and a liquid phase forming metal part with a lower melting start temperature than the solid phase forming metal part, the joining bumps being composed so that at the joining temperature, at least part of the liquid phase forming metal part melts to form a liquid phase material (Claim 7).

[0016] That is, according to the circuit board with the above composition, the joining bumps are constructed of two parts with different melting start temperatures, that is the solid phase forming metal part with a high melting start temperature and the liquid phase forming metal part with a low melting start temperature. At the joining temperature, the liquid phase forming metal part at least partially melts to produce liquid state material, while at least part of the solid phase forming metal part maintains the solid phase, so that at the joining temperature a state is formed where the liquid phase part and the solid phase part are mixed together. Accordingly, during joining, it is difficult for problems such as the bumps collapsing to occur, and favorable joins can be formed with the joined object. The joining temperature can be set between the melting start temperature of the solid phase forming metal part and the melting start temperature of the liquid phase forming metal part, for example.

[0017] More specifically, the joining bumps can be formed of a composite material with a large number of metal particles as the solid phase forming metal part and a combining metal part that fills at least part of the gaps between the metal particles as the liquid phase forming metal part (Claim 8). Also, the circuit board according to Claim 9 has a substrate and a plurality of joining bumps disposed on a joining surface thereof, the joining bumps being composed of a composite material with a large number of metal particles and a combining metal part which fills at least part of the gaps between the metal particles and is composed of a metal with a lower melting start temperature than a metal composing the metal particles.

[0018] As one example, in the case of the joining bumps of the circuit board of Claim 2, it is necessary to select special constituents as the material forming the bumps so that at the joining temperature the proportion of solid phase falls within the described predetermined range, but with the above construction, the bumps are composed of a composite material in which a large number of metal particles are disposed in the combining metal part, so that there is the advantage that the combination of materials for the combining metal part and the metal particles can be selected with relative freedom. Also, since it is sufficient to prepare a composite material in which the combining metal part and the metal particles are mixed and dispersed, and to form the joining bumps using this composite material, it is not necessary to use a step or equipment for mounting balls, as is the case with conventional bumps that enclose balls. This means that the manufacturing cost can be reduced and small bumps can be manufactured easily.

[0019] It should be noted that with the above construction, the included amount of the metal particles is adjusted so that at the joining temperature at least, for example, a temperature range of 200 to 220°C, a proportion of solid phase is 20 to 95% by weight, and preferably 40 to 70% by weight. Here, the significance of the critical values is the same as for the circuit board of Claim 2. In this case, when a majority of the combining metal part is in the liquid phase at the joining temperature, the included amount of the metal particles in the composite material should be adjusted to a range of 20 to 95% by weight, and preferably 40 to 70% by weight.

[0020] The bumps formed using the composite material described above can be formed, for example, using the solder pasting method where a predetermined bump pattern is formed on the substrate using a paste produced by mixing metal powder that forms the combining metal material and the metal particles in advance, and then heating this to a melting start temperature or above of the material composing the combining metal material, for example, so that at least some of the metal powder composing the combining metal material melts and integrates the composite material. On the other hand, it is also possible to use a performing method that forms the bumps by (i) producing the composite material in which the metal particles have been dispersed in the combining metal part, for example, by mixing metal particles and metal powder as the combining metal part, (ii) producing performs by molding the composite material into predetermined shapes using a suitable method, such as firing or extrusion molding, and (iii) integrating the performs with the substrate by mounting the performs on the substrate and heating.

[0021] When the bumps are formed using a composite material such as that described above, to increase the retentivity of the form of the bumps during the joining process, it is preferable to select a material with suitable wettability with respect to the combining metal part as the metal particles so that a suitable frictional force acts between the metal particles and the liquid phase produced when the combining metal part melts and the metal particles are evenly dispersed in the combining metal part.

[0022] Also, the joining bumps can be composed so as to include a structure in which an alloy layer, including some component of the combining metal part and some component of the metal particles, is formed on the surfaces of the metal particles, with the metal particles being joined together via this alloy layer (Claim 10). By doing so, the metal particles (that is, the solid phase part) can be joined together via the alloy layers, so that a skeletal structure in the form of a three-dimensional mesh, for example, is formed and the retentivity of the form of the bumps during the joining process is increased further. This alloy layer can be formed by eluting, out of the liquid phase produced by melting the combining metal part, a component of the metal particles to a part located close to the interface with the metal particles and raising the temperature of such component to the melting start temperature (solidus temperature), and solidifying the liquid phase of such parts (Claim 11).

[0023] This combining metal part is preferably composed of a material that can quickly melt and produce a sufficient amount of liquid phase at the joining temperature, and specifically can be composed of an alloy including 50 to 80% by weight of Sn (Claim 12). In this case, the combining metal part can be composed with Pb as the

main component of the remaining part aside from the Sn component (Claim 13). More specifically, an Sn-Pb binary alloy (so-called "Sn-Pb eutectic solder" with 38.1% by weight of Sn) or an Sn-Pb binary alloy with a similar composition (for example, with 20 to 50% by weight of Pb) can be used. As the metal particles, it is possible to use a material with favorable wettability for the liquid phase that is based on the combining metal part, for example, one or two or more kinds of metal particles composed with at least one of Pb, Cu, and Ag as a main component (Claim 14). For example, in the case of metal particles that have Pb as a main component, it is possible to use Pb metal particles and particles of a Pb-Sn binary alloy (so-called high melting point solder) that include at least 90% by weight of Pb, or Cu or Cu alloy particles as metal particles that have Cu as a main component. It is also possible to use particles of alloy that includes two or more types of Pb, Cu, and Ag, for example particles of Ag-Cu alloy. It should be noted that the metal particles can all be composed of the same material or a mixture of two or more different materials can be used.